MODIS SEMI-ANNUAL REPORT: JAN/01/98 - JUN/30/98

Radiative Transfer Based Synergistic MODIS/MISR Algorithm for the Estimation of Global LAI & FPAR

Contract: NAS5-96061

Y. Zhang, Y. Tian, A. Lotsch, Y. Knjazikhin, K. Tabor and R. B. Myneni

Geography Department, Boston University, 675 Commonwealth Avenue, Boston, MA 02215

Summary of the algorithm. The objective of the contract is to develop a radiative transfer based synergistic algorithm for estimation of global leaf area index (LAI) and fraction of photosynthetically active radiation absorbed by vegetation (FPAR). The algorithm consists of a main procedure that exploits the spectral information content of MODIS measurements and the angular information content of MISR measurements to derive accurate estimation of LAI and FPAR. Should this main algorithm fail, a backup algorithm is triggered to estimate LAI and FPAR using vegetation indices. Both algorithms are capable of executing in MODIS-only or MISR-only mode, should cloud contamination, data frequency and spatial or temporal resolution requirements hinder a joint MODIS/MISR mode of operation. The MODIS-only mode of the algorithm requires a land cover classification that is compatible with the radiative transfer model used in the derivation. Such a classification based on vegetation structure was proposed and it is expected to be derived from the MODIS Land Cover Product. Therefore, our algorithm has interfaces with the MODIS/MISR surface reflectance product and the MODIS Land Cover Product. Validation of the LAI/FPAR is an important part of algorithm development. Multiple validation techniques will be used to develop uncertainty information on Terra LAI/FPAR products. Successful validation will be accomplished if timely and accurate product uncertainty information becomes routinely available to the product users within two years after Terra's launch.

Summary of work performed during the second half of 1999 (January through June)

1. The MODIS version of the algorithm was modified and delivered to the University of Montana. A new version accounts for band-specific uncertainties of MOD-09 BRDF product.
2. Six papers describing the algorithm and prototyping results have been submitted for publication.
3. A fine resolution (1km) global biome classification map has been derived from many data sources.
4. MOD15 ATBD (Algorithm Theoretical Basis Documents) has been rewritten. Version 4.0 is available at *<u>http://eospso.gsfc.nasa.gov/atbd/modistables.html</u>*
5. QA process for simulated data is underway during the N-day and X-day tests. Golden tiles have been selected for the initial QA efforts. Sufficient preparations have been made for the processing of coming test data from the MOSS-2 and Y-day tests.
6. Preparation has been made for MODIS LAI/FPAR product validation activities - KonVEX field campaign (July 11 – July 17, 1999).
7. Results from prototyping of the LAI/FPAR algorithm were presented at the International conference: "the contribution of POLDER and new generation space born sensors to global change studies", January 18-22, 1999, Mèribel, France (Myneni and Knyazikhin).
8. Theoretical aspects of the retrieval techniques for geophysical parameters were presented at the 1999 Spring meeting of AGU in Boston, June 1 – June 4, 1999.
9. Myneni made a presentation on the result of two-year activities at the NASA-IWG (Investigator Working Group) meeting in Vail, June 15-17, 1999.

At-Launch Land Cover Classification

An accurate land cover map is a prerequisite for choosing the appropriate relation between surface parameters (LAI and FPAR) and the satellite derived reflectances. Global land cover maps with 1-km resolution are currently available from University of Maryland (UMD) and the Earth Resources Observation System (EROS) Data Center (EDC). The map from UMD was used in association with the SLCR map to generate a 6-biome scheme map for the MODIS/MISR LAI/FPAR algorithm. More specifically, a direct class assignment was performed for those classes in the UMD-IGBP scheme that can be directly translated into one of the biome classes. This applies to evergreen needle leaf forests, evergreen broadleaf forests, deciduous needle leaf forests, deciduous broadleaf forests, wooded grassland, open shrubland, grasslands, bare ground, and urban/built-up. For classes that do not allow a direct translation, the respective SLCR label was retrieved and a biome class label was assigned using the IGBP-biome LUT described in [3]. This routine was performed on a per-pixel basis. The global biome classification map is shown is figure 1.

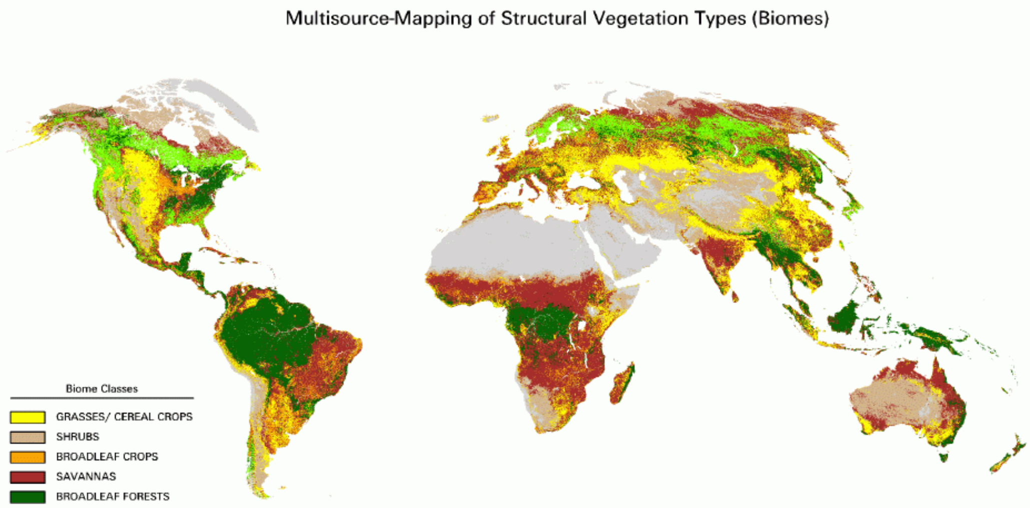

Figure 1: *At-launch global biome map derived from the UMD land cover map and the EDC SLCR map*.

The use of the SLCR maps in conjunction with the ancillary information in the global land cover characterization data base allow for resolving ambiguities when translating the UMD map into the 6-biome scheme. The SLCR labels were particularly useful for disaggregating the cropland class into broadleaf crops and cereal crops. The ancillary information about structural properties of the land cover types in the GLCC database also helped separate the closed shrubland and woody savannas classes. However, the disaggregation of mixed forests into either needle leaf forests or broadleaf forests remained ambiguous in many cases since many areas are in fact characterized by a mixture of both forest types. Using the LUT for each of the five continents, each pixel labeled according to the biome scheme can be related to its original class label in the UMD land cover map. This allows for comparing the various MODIS products (e.g. net primary productivity or leaf area index) that used modified versions of the UMD map in their algorithm.

Biome Structural Difference

Distribution of vegetated pixels from LASUR data with respect to their reflectances at red and NIR wavelengths are shown in Figure 2. Each biome-dependent contour separates a set of pixels representing the most probable patterns of canopy structure from a given biome type. Pixels having the same value of NDVI lie on a single line in the red-NIR spectral space. One can see that canopy structure can vary considerably with NDVI unchanged. Prototyping of the MISR LAI and FPAR with POLDER data shows that the use of multi-angle data can help to identify the biome type.

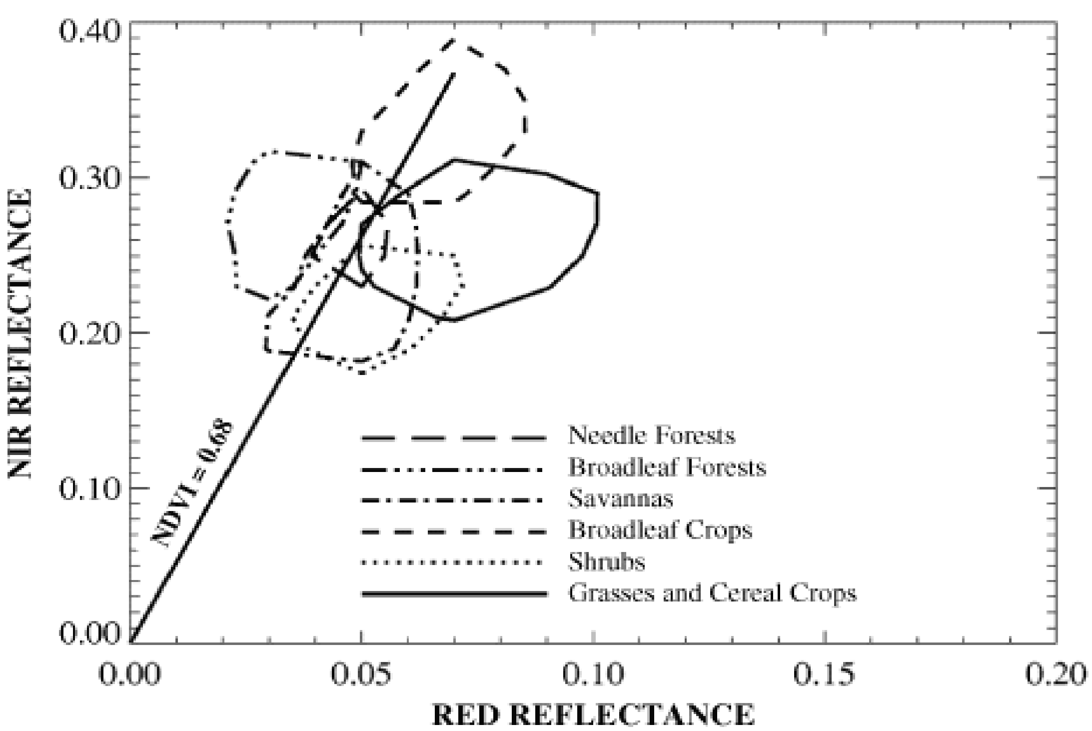

Figure 2 *Six biomes' 25% density contours of LASUR data .*

Spatial Resolution Effects

The impact of spatial resolution and aggregation of data on the MODIS LAI/FPAR algorithm was investigated. The study focused mainly on broadleaf and needle leaf forests. A 30 m resolution landcover map was used as the baseline data set. This map was used to label a series of coarser resolution maps of the scene, which were produced by an aggregation procedure described below. The 30 m resolution pixels were averaged to 240 m and 510 m resolution. Each grid at the 240 m aggregation contained 64 30 m pixels. These were overlaid on the 30 m class map and the coarse grid cell was labeled based on the most frequently occurring cover type among the high resolution pixels within that grid. This procedure was performed for both resolutions. Here, we use two TM images of the same area, but from different seasons. One of these is from June 27, 1987 and the other is from September 30, 1987.

From a spectral and NDVI point of view, the biomes change differently as the resolution decreases (Table I (a) and (b)). Consider the June image. As resolution decreases, the RED reflectance of broadleaf forests increases and the NIR simultaneously decreases with the result that NDVI decreases. For needle leaf forests, the RED as well as the NIR reflectance increases, consequently, NDVI is unchanged. In the RED-NIR space, these changes can be clearly seen (Figure 3). The distance between the three biomes decreases, that is, the biomes become spectrally similar as resolution decreases. The September image shows similar changes (Figure 4), but the difference between the two images can be attributed to changing seasonality. The reason why needle leaf forests exhibit such a large seasonal change is perhaps due to the understory. It is important to note the distinct separation between the three biomes in both the images. This suggests that seasonal changes do not confound differences between the biomes. The reason why NIR reflectance in needle leaf forests increases with decreasing resolution is due to the forests low NIR reflectance compared to the two other biomes. Indeed, the spectral properties of coarse resolution data aggregated from fine resolution are also influenced by landscape characteristics. However, in general, the RED reflectance increases with the result that the biomes tend to move toward the soil line in the RED-NIR space.

The MODIS LAI/FPAR algorithm was executed with the above mentioned multiple resolution data and the 30 m LUT. The results indicate that as resolution gets coarser, the mean LAI of broadleaf forests decreases, but increases in needle leaf forests. This is in agreement with the changes seen in the spectral data discussed previously.

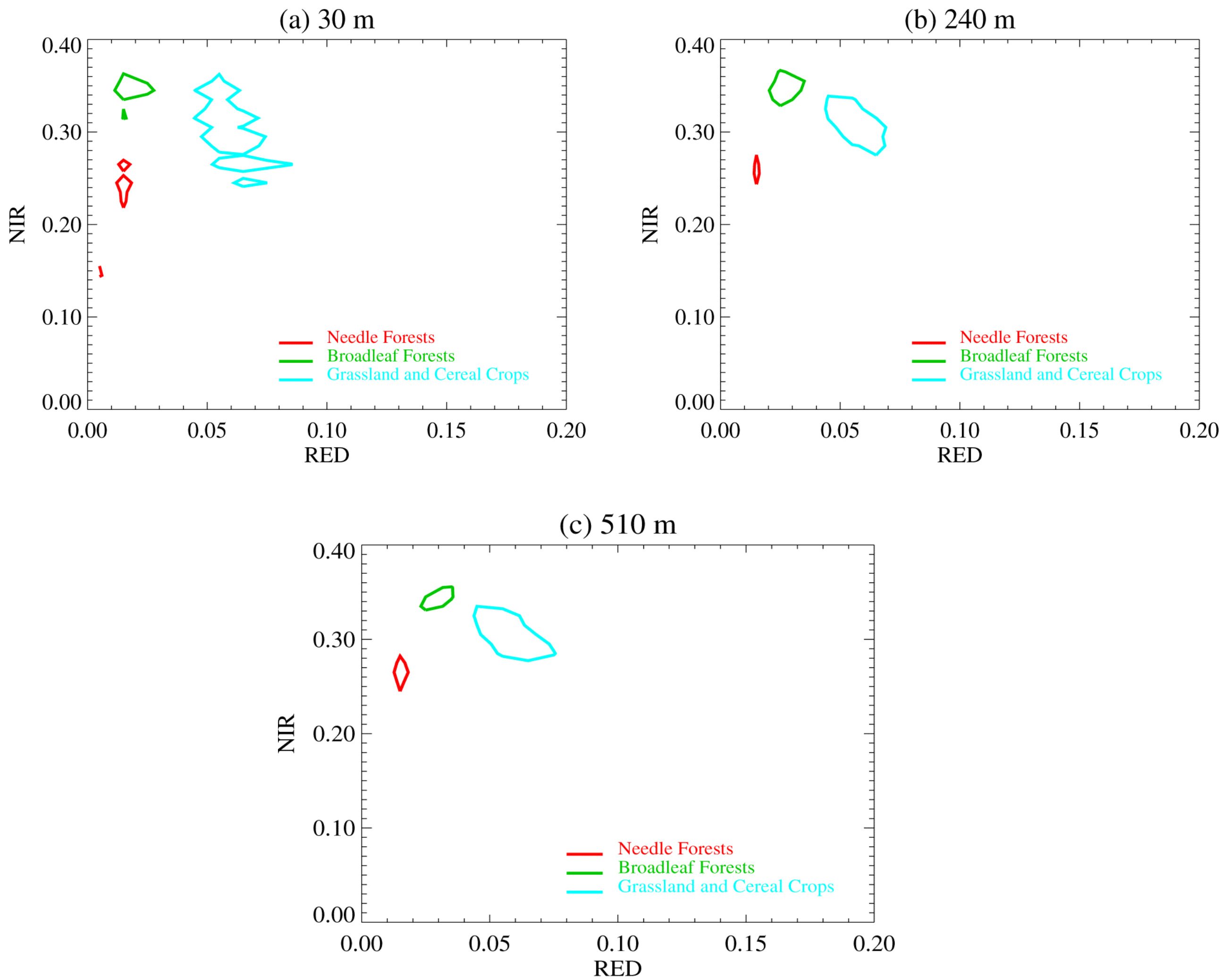

Figure 3 *25% density contours of Landsat TM data on June 30, 1987 at (a) 30 m resolution, (b) 240 m resolution, and (c) 510 m resolution The 30 m resolution pixels were averaged to 240 m and 510 m resolution. A 30 m resolution landcover map was used as the baseline data set. The coarse resolution map was overlaid on the 30 m class map and the coarse grid cell was labeled based on the most frequently occurring cover type among the 30 m resolution pixels within that grid.*

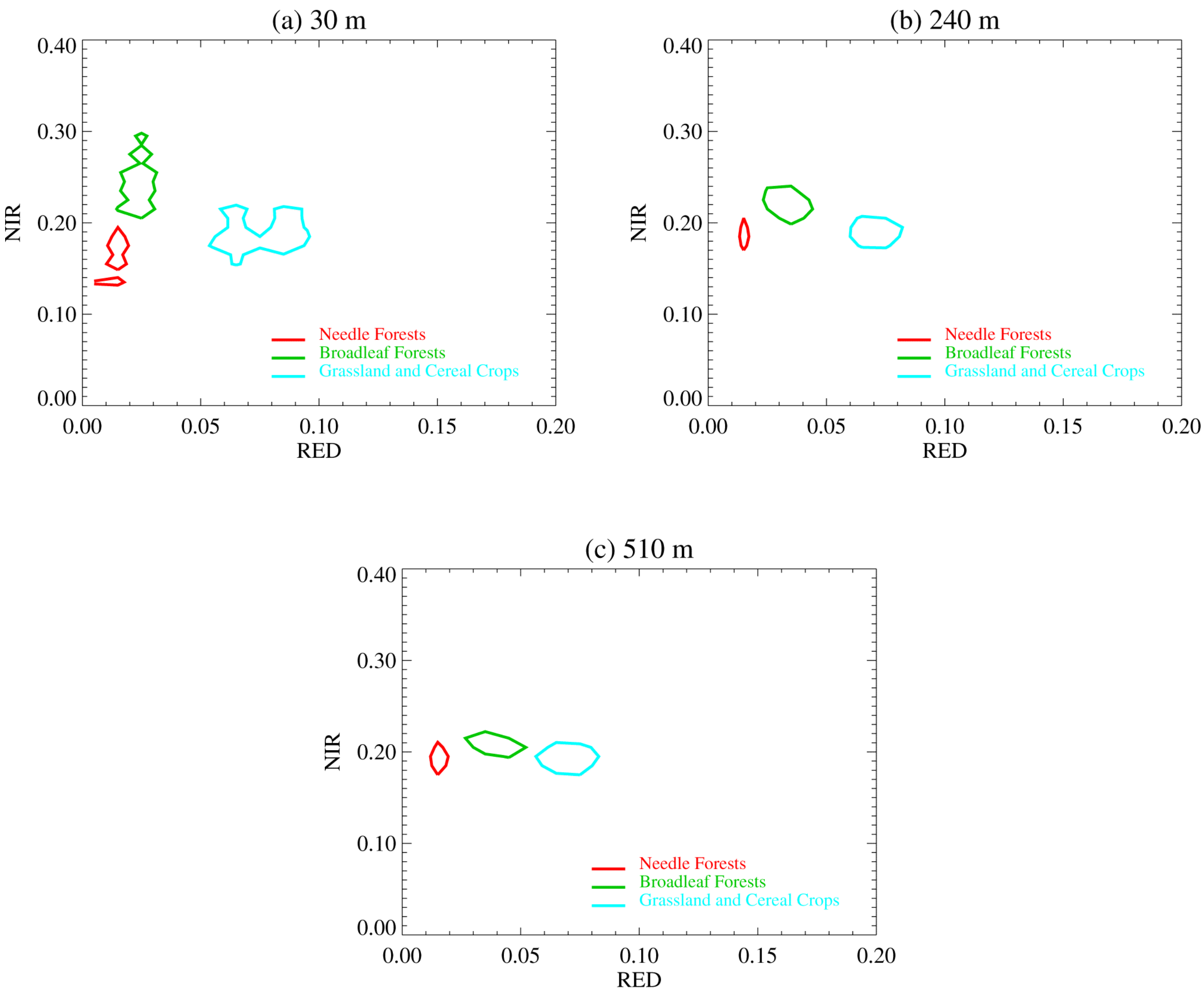

***Figure 4** Same as Figure above, data come from September 30, 1987.*

TABLE I

MEAN VALUES OF RED, NIR, NDVI AND LAI AT 30 m, 240 m AND 510 m RESOLUTION FOR LANDSAT TM DATA ON (a) JUNE 30, 1987, AND (b) SEPTEMBER 30, 1987

	30 m * 30 m			
Biome Type	Mean Red	Mean NIR	Mean NDVI	Mean LAI
Grasses and Cereal Crops	0.0655	0.304	0.635	1.87
Broadleaf Forests	0.0215	0.348	0.881	5.79
Needle Leaf Forests	0.0131	0.200	0.886	4.11
	240 m * 240 m			
Biome Type	Mean Red	Mean NIR	Mean NDVI	Mean LAI
Grasses and Cereal Crops	0.0646	0.295	0.635	1.795
Broadleaf Forests	0.0275	0.346	0.853	5.385
Needle Leaf Forests	0.0141	0.232	0.889	4.488
	510 m * 510 m			
Biome Type	Mean Red	Mean NIR	Mean NDVI	Mean LAI
Grasses and Cereal Crops	0.0640	0.291	0.635	1.756
Broadleaf Forests	0.0307	0.342	0.835	5.282
Needle Leaf Forests	0.0158	0.246	0.883	4.584

(a)

	30 m * 30 m			
Biome Type	Mean Red	Mean NIR	Mean NDVI	Mean LAI
Grasses and Cereal Crops	0.0697	0.208	0.492	1.261
Broadleaf Forests	0.0310	0.234	0.763	2.438
Needle Leaf Forests	0.0138	0.154	0.842	2.365
	240 m * 240 m			
Biome Type	Mean Red	Mean NIR	Mean NDVI	Mean LAI
Grasses and Cereal Crops	0.0718	0.200	0.1472	1.043
Broadleaf Forests	0.0378	0.225	0.712	1.889
Needle Leaf Forests	0.0149	0.166	0.845	2.619
	510 m * 510 m			
Biome Type	Mean Red	Mean NIR	Mean NDVI	Mean LAI
Grasses and Cereal Crops	0.0711	0.199	0.434	1.028
Broadleaf Forests	0.0415	0.219	0.683	1.630
Needle Leaf Forests	0.0164	0.176	0.837	2.681

(b)

** *The 30 m resolution pixels were averaged to 240 m and 510 m resolution. A 30 m resolution landcover map was used as the baseline data set. The coarse resolution map was overlaid on the 30 m class map and the coarse grid cell was labeled based on the most frequently occurring cover type among the 30 m resolution pixels within that grid.*

QA Process and Golden Tiles

The MOD15A1 and MOD15A2 algorithms, like most MODIS Land processes, are organized to accept global coverage inputs, and produce global coverages either daily (PGE-33) or on an 8-day (PGE-34) timestep. Rather than process synoptic 1 KM spatial resolution images, the MODIS Land team has adopted a contiguous land tile scheme based on the Integerized Sinusoidal Grid -- a map projection derived from the sinusoidal map projection (with the General Cartographic Map Projection code of GCTP_ISINUS). This projection defines a total of 648 tiles, globally, at 10 degree resolution. We currently estimate that ***289 tiles of 648*** will be classified as "land" tiles, and thus represent the maximum spatial extent that our global algorithms will process. In the preliminary stage of QA process, about 5% of 289 tiles (i.e. 15 tiles) have been assigned as golden tiles for the first round of examination. The selections are based on covering all kind of biome types and also accounting for the location of validation sites. The selections are also discussed with UMT and demonstrated in the following map (Figure 5).

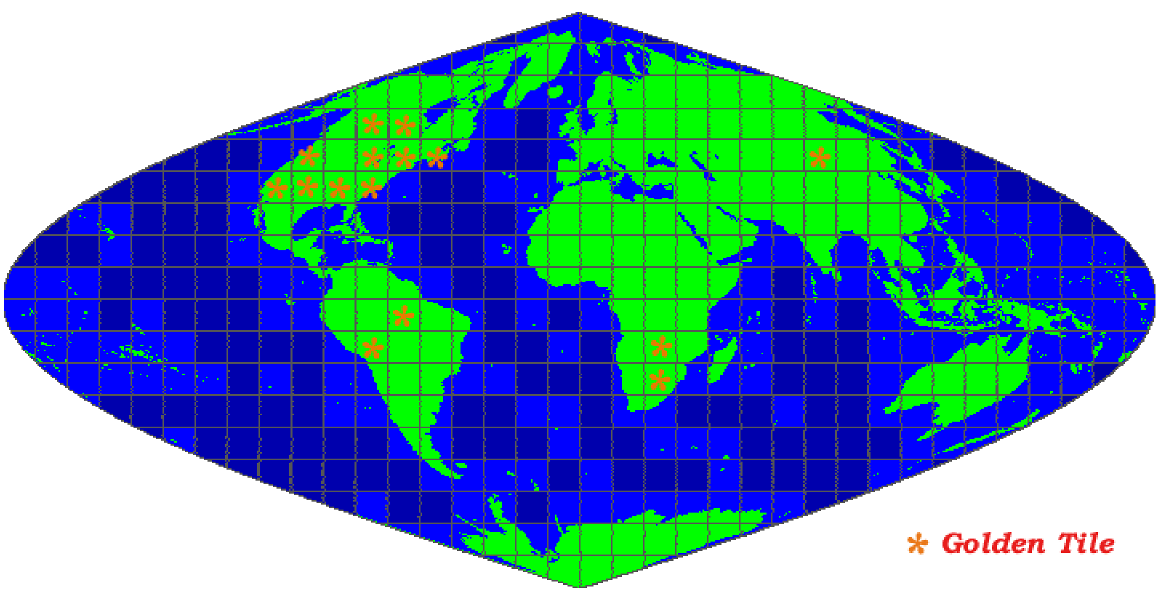

Figure 5*: Golden tiles for QA process of MODIS PGE33, 34 LAI/FPAR product*.

Conclusions

- 1-km resolution biome classification maps derived from many data sources are available. Biome structure information is important for LAI/FPAR retrieval algorithm, therefore, a biome classification map is an important ancillary dataset for algorithm.

- The quality of the retrievals can be improved by introducing the band specified uncertainties, when the information about uncertainties in spectral canopy reflectances are available.

- QA and validation of the LAI/FPAR algorithm are undergoing with continuous preparations.

Paper List

[1] Y. Tian, Y. Zhang, Y. Knyazikhin, R. B. Myneni, and S. W. Running, "Prototyping of MODIS LAI/FPAR algorithm with LASUR and Landsat data", *IEEE Transaction on Geoscience and Remote Sensing*, (submitted for publication), 1999.

[2] Y. Zhang, Y. Tian, Y. Knyazikhin, J. V. Martonchik, D. J. Diner, M. Leroy, R. B. Myneni, "Prototyping of MISR LAI/FPAR algorithm with POLDER data over Africa", *IEEE Transaction on Geoscience and Remote Sensing*, (submitted for publication), 1999.

[3] Alexander Lotsch, "Biome Level Classification of Land Cover at Continental Scales Using Decision Trees", (Master thesis), Boston University, 1999.

[4] Y. Knjazikhin, A. Marshak, "Mathematical aspects of BRDF modeling: Adjoint problem and Green's Function, *Remote Sensing Reviews,* (submitted for publication), 1999.

[5] D. J. Diner, G. P. Asner, R. Davies, Y. Knyazikhin, J-P, Muller, A. W. Nolin, B. Pinty, C. B. Schaaf, and J. Stroeve, "New directions in Earth observing: Scientific applications of multi-angle remote sensing", (accepted for publication in Bulletin of the American Meteorological Society), 1999.

[6] D. Kimes, Y. Knjazikhin, J. Privette, A. Abuelgasim, F. Gao, "Inversion methods for Physically-based Models", *Remote Sensing Reviews,* (submitted for publication), 1999.

[7] M. Weiss, F. Baret, R. B. Myneni, A. Pragnere, Y. Knyazikhin, "Investigation of a model inversion technique for the estimation of crop characteristics from spectral and directional reflectance data", *Agronomie,* (accepted for publication), 1999.

- Papers submitted for publication are available at
  http://cybele.bu.edu/download/download.html